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DEFENCE RESEARCH ESTABLISHMENT OTTAWA
TECHNICAL NOTE 84-26

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Environmental Protection Section
Protective Sciences Division

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ABSTRACT

The provision of thermal protection for the poorly-insulated hands of satellite-tracking telescope operators working in the cold was investigated. It was found that, as predicted, if additional insulation was applied to the whole body of the man, the temperature of his hands could be maintained for a longer period of time. Additional keywords: Canada; French language.

RÉSUMÉ

La possibilité d'offrir une protection thermique pour les mains des opérateurs de télescopes destinés au repérage de satellites, lorsque ces personnes travaillent au froid, a fait l'objet d'une étude. On a découvert, comme prévu, que si le corps de ces personnes est recouvert d'une couche isolante supplémentaire, la température de leurs mains peut être maintenue pendant plus longtemps.

INTRODUCTION

Thermal protection of personnel who must remain relatively inactive while performing tasks outdoors in the cold is a continuing problem. Provision of comfort and allowing for mobility are design requirements as important as protection from the cold. A further difficulty experienced by persons working in the cold at tasks for which manual dexterity is required is thermal protection of the hands. In such situations only very light handwear can be worn and often, mitts or gloves must be removed in order to perform the task.

A particular example of such a task exists at the CF Satellite Tracking and Identification Unit (S.I.T.U.) at St. Margaret's, New Brunswick. The telescope (Figure 1) which is used for tracking satellites is located outdoors when operational. To minimize optical interference, the area around the telescope cannot be heated in winter. During the course of the tracking sequence, which takes about 30 minutes, the operator must be in contact with the large metal mass of the telescope. In addition, the operation of the steering control button requires that if any handwear is worn, it must be very thin. Operating temperatures as low as -20°C are often experienced. → see p iii

There are two ways in which hands may be kept warm when exposed to cold conditions. One may either decrease the heat loss from the hands by adding insulation or increase the heat flow to this area. In the satellite-tracking task, a relatively high degree of manual dexterity is required. Fingers must be free and sensitive to the touch of buttons on the control panel. Since manual dexterity would be degraded if additional insulation were provided to the hands, the only other option is to increase the heat flow to them.

One method of providing greater heat flow to the hands is to increase activity (metabolic rate) and, thus, rate of heat production. However, in the satellite-tracking task, the operator must remain relatively motionless and as a result his rate of heat production is relatively low (about 100 watts).

If his rate of heat production is lower than his rate of heat loss, a man will cool. It has been shown that when this occurs, humans cool in a preferential sequence with extremities cooling before the torso as the body attempts to conserve heat (1). Therefore if a man is cooling, it is very difficult for him to prevent his hands cooling. In other words, the best way to keep the hands warm is to reduce the rate of heat loss from the whole body. Reduction of the rate of heat loss from the body by adding

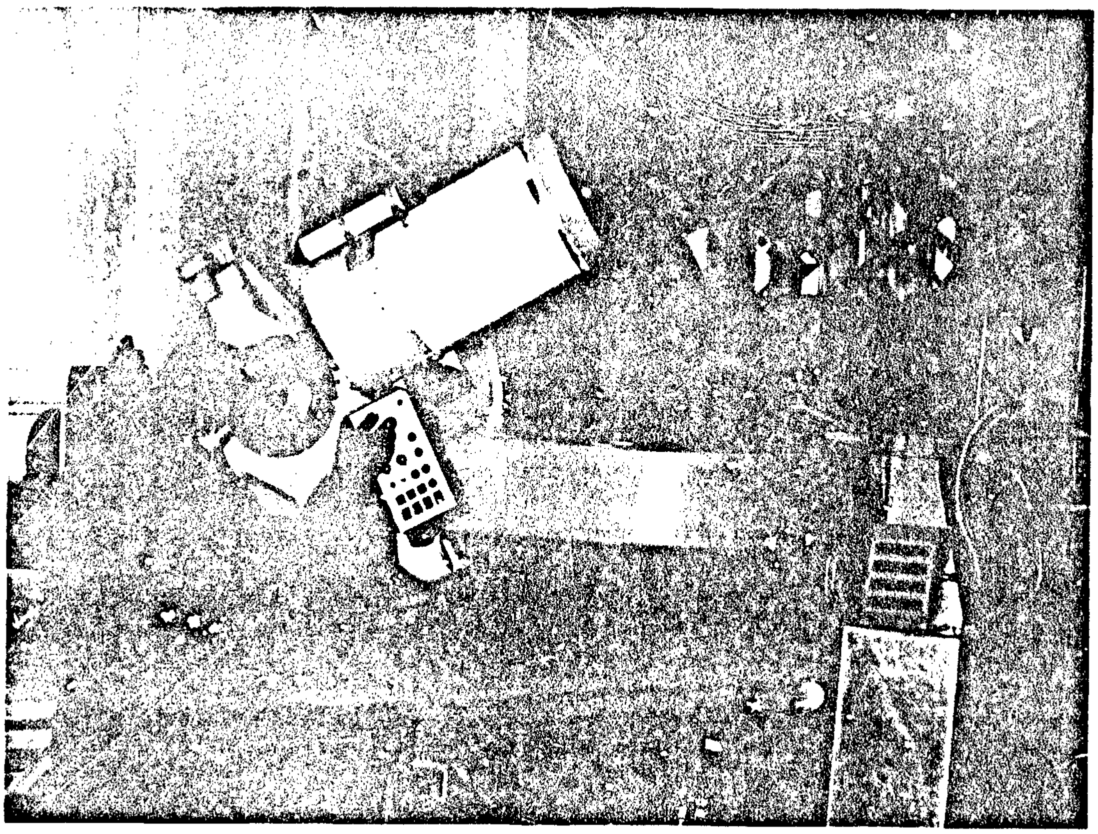

Figure 1: Satellite Tracking Telescope.

insulation will result in a greater flow of heat to the hands, thus keeping them at a higher temperature.

In response to a r est from the Commanding Officer at S.I.T.U. to the Directorate of Genera, Engineering and Maintenance (DCGEM) (2), a study was undertaken at DREO at DCGEM's request to determine whether the cold stress problem being experienced during a tracking task could be alleviated by providing additional insulation to the torso. The study was done in two phases, the first of which was conducted in the laboratory under controlled conditions. The second phase was conducted at St. Margaret's to confirm that the results obtained in the laboratory could be repeated in the field.

METHOD - LABORATORY TRIAL

SUBJECTS

In the laboratory four members of the CF/DREO Test Team volunteered to participate in the experiment. They were active male military personnel whose anthropometric characteristics are given in Table 1.

TABLE I

Anthropometric Characteristics of Test Subjects

Subject	Age (Years)	Height (cm)	Weight (kg)
A	29	173	72
B	22	175	76
C	22	180	71
D	25	170	59

CLOTHING WORN

In order to provide the additional insulation required by theoretical predictions, a prototype parka and trousers designed to provide about 1.5 times as much thermal protection as the standard CF parka were manufactured in the laboratory. Calculations indicated that the insulation provided by this ensemble was sufficient to keep a relatively inactive man in thermal equilibrium at -20°C.

The following items of standard CF Arctic clothing were worn by each of the test subjects:

NSN 8415-21-859-0726 - Drawers, extreme cold weather
NSN 8415-21-859-0731 - Undershirt, extreme cold weather
NSN 8415-21-868-7806 - Shirt, flannel, cold weather
NSN 8415-21-866-1502 - Coat, combat, men's, OG 107, GS
NSN 8415-21-866-1514 - Liner, men's coat, combat, OG 107, GS
NSN 8415-21-840-8552 - Trousers, combat, men's, OG 107, GS
NSN 8440-21-104-2859 - Socks, men's, long
NSN 8440-21-103-7669 - Socks, men's, wool, frieze
NSN 8430-21-104-6909 - Boots, mukluk, extreme cold weather
NSN 8415-21-103-8356 - Gloves, anti-contact
\- Balaclava

In addition to the above, subjects wore either the CF parka, extreme cold weather (NSN 8415-21-870-5571), referred to in Table II as the CF ensemble (CF), or the prototype parka and trousers, referred to as the experimental (EX) ensemble.

TABLE II

Clothing Worn by Test Subjects

Subject	Day 1	Day 2
A	EX	CF
B	CF	EX
C	CF	EX
D	EX	CF

PROTOCOL

Before dressing for the test each subject had 12 YSI type 44004 thermistors attached to the skin at the various sites shown in Figure 2 using Blenderm surgical tape (3M Company) and had a rectal thermistor probe inserted 15 cm into the anus. Additional thermistors were taped to the large toe on the right foot and to the middle and small fingers of the left hand. The subject then dressed in either normal CF Arctic clothing or the experimental clothing (EX) as scheduled in Table II. After dressing, he entered an environmental chamber controlled at -20°C and operated the controls of a simulated satellite tracking device for a period of 30 minutes or until he felt uncomfortably cold or any skin temperature fell below 5°C.

The satellite tracking telescope was simulated by attaching the joystick control of a personal computer to a 100-centimeter-long bar of four-inch steel channel, representing the heat sink of the actual telescope. During the experiment, the subject's gloved hand remained in contact with the steel bar and used the joystick to control a video game on a monitor, simulating the operation of the controls on the telescope. The simulated device is shown in Figure 3. His other hand was allowed to remain in any position the subject deemed comfortable.

While the subjects were in the environmental chamber, temperatures were taken every minute using an automated data acquisition system (3497A Data Acquisition/Control Unit and HP 85 computer, Hewlett Packard) which was used to measure the resistance of each thermistor and to calculate the corresponding temperatures. These readings were then stored on magnetic tape for subsequent analysis. Mean skin temperatures (3) and mean body temperatures (4) were calculated as in the following formulas:

$$T_s = .07\,T_1 + .085\,T_2 + .065\,T_3 + .085\,T_4$$
$$+ .14\,T_5 + .05\,T_6 + .095\,T_7 + .065\,T_8$$
$$+ .07\,T_9 + .09\,T_{10} + .09\,T_{11} + .095\,T_{12}$$
$$T_b = .67\,T_{13} + .33\,T_s$$

where T_s = mean skin temperature
T_b = mean body temperature
T_1 = forehead temperature
T_2 = chest temperature
T_3 = rear calf temperature

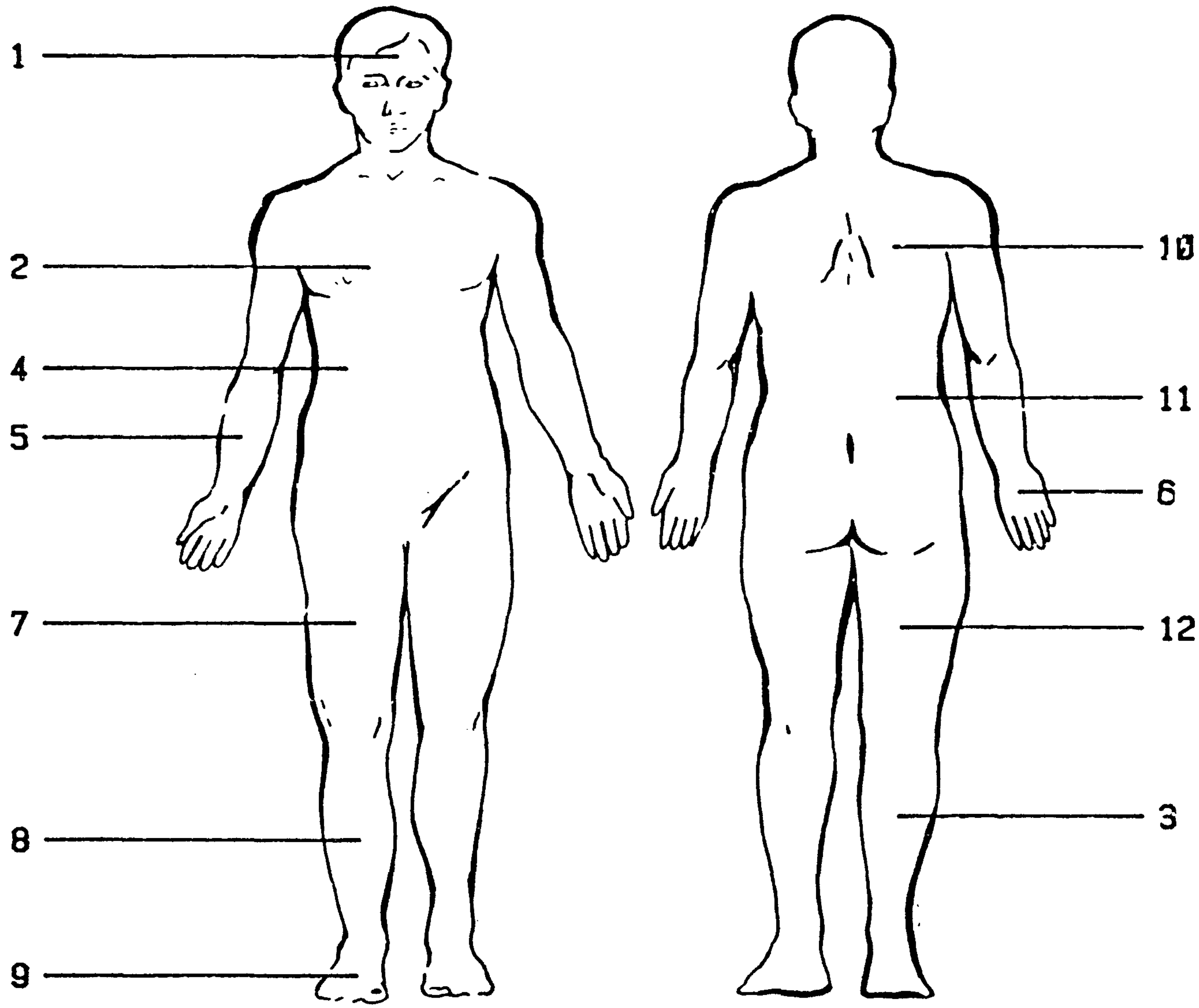

Figure 2: Location of Thermistors.

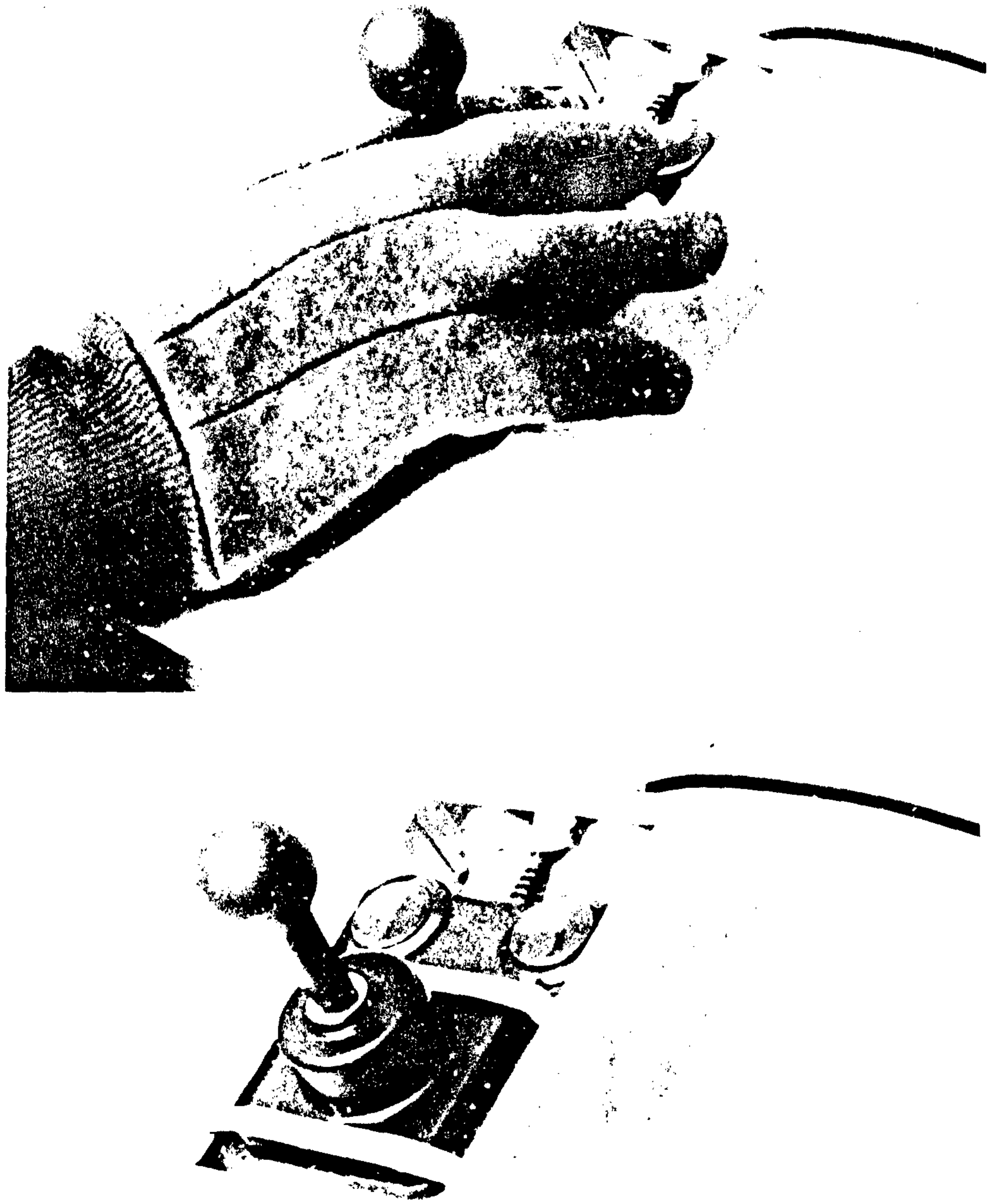

Figure 3: Simulated Operating Controls.

T_4 = abdomen temperature
T_5 = lower arm temperature
T_6 = back of hand temperature
T_7 = thigh temperature
T_8 = front calf temperature
T_9 = foot temperature
T_{10} = upper back temperature
T_{11} = lower back temperature
T_{12} = rear thigh temperature
T_{13} = rectal temperature

METHOD - FIELD TRIAL

Since the experimental parka and trousers did not meet the specifications of quick dressing and undressing, an extra-large one-piece commercial snowmobile suit with zippers in the trousers and in the front was purchased and modified by lining it - body, arms and legs - with two layers of Thinsulate 150 (3M Company) quilted to a nylon shell. Calculations indicated that the extra insulation provided was equivalent to that of the experimental clothing. The modified snowmobile suit was sent to St. Margaret's for testing by personnel at S.I.T.U. during actual working conditions in late winter of 1983-84.

RESULTS AND DISCUSSION

Average temperatures of the four subjects when wearing either the CF ensemble or the experimental ensemble were calculated and plotted as a function of time. Average rectal, mean skin, mean body and toe temperatures are shown in Figure 4 and average finger temperatures are shown in Figure 5. Results indicate that no difference in the evolution of rectal temperature was measured when either ensemble was worn but neither the mean skin nor the mean body temperature fell as rapidly when the experimental clothing was worn. Mean skin temperature was about two degrees higher at the end of the 30 minute test period with the experimental ensemble. Toe temperature also fell more rapidly in the CF clothing.

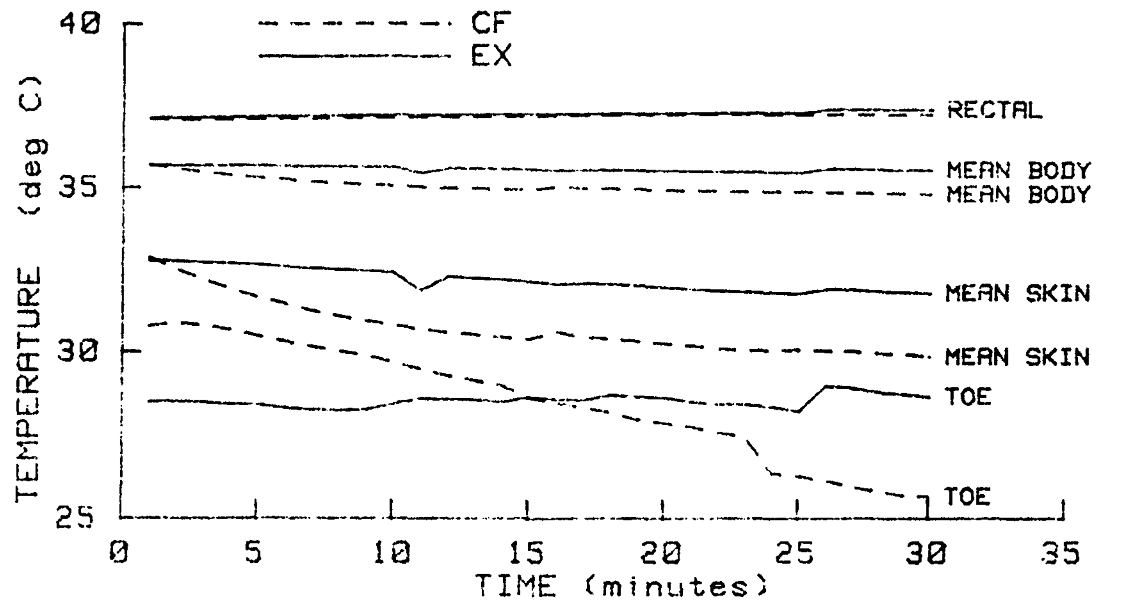

Figure 4 - Average Rectal, Mean Skin and Mean Body Temperatures as a Function of Time

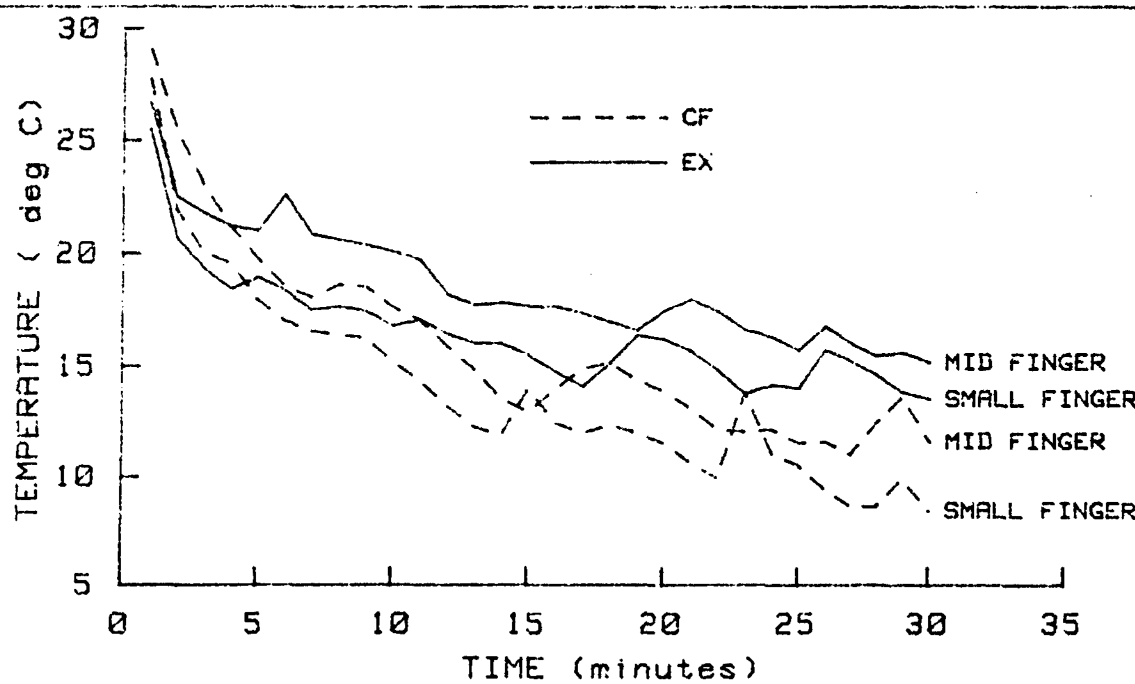

Figure 5 - Average Finger Temperatures as a Function of Time

The most striking observation was that the fingers stayed warmer when the experimental clothing was worn even though in both cases the identical gloves were used. In fact, two subjects could not complete the experiment when wearing the CF clothing because their finger temperatures fell below 5°C. This result is masked when average temperatures are plotted but can clearly be seen in Figure 6 where individual finger temperatures are shown.

Results from the field trials at St. Margaret's (5) indicated that although the modified snowmobile suit kept personnel warm, the suit was too bulky and cumbersome for their use. The satellite tracking crews felt too restricted in their movements and also felt that the suit exerted an uncomfortable amount of pressure at some of the joints such as the knees.

From the results of our experiments, it appears that the above theory is valid and that poorly-insulated hands are indeed kept warmer when a man's whole body is better insulated as expected. In this particular instance the means of providing the extra insulation was not satisfactory, since the resulting clothing was too bulky and cumbersome and restricted the movement of the wearers. Other solutions such as some type of localized auxiliary heating of the body or of the hands which does not affect the viewing apparatus may have to be employed.

CONCLUSIONS

Under the conditions of our experiment, it has been confirmed that the addition of insulation to the whole body of a relatively inactive man in the cold maintains the temperature of poorly-insulated hands for a longer period of time albeit with inconvenience of wearing bulky clothing which restricts body motion.

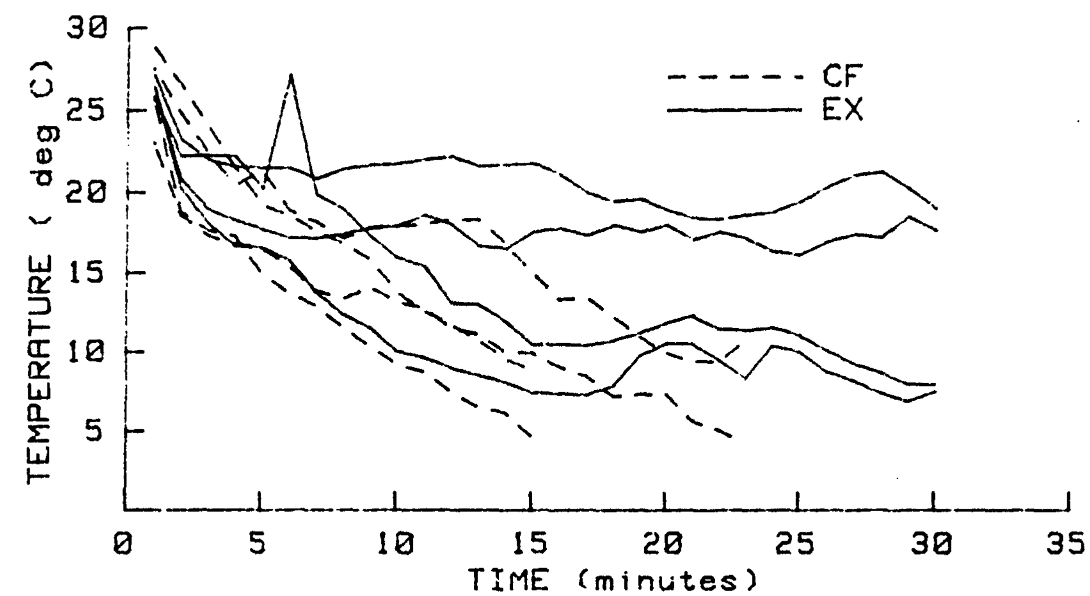

Figure 6 - Individual Finger Temperatures as a Function of Time

ACKNOWLEDGEMENT

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